5G-ACIA White Paper

Service-Level Specifications (SLSs) for 5G Technology-Enabled Connected Industries

5G Alliance for Connected Industries and Automation

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Executive Summary

5G is poised to become the first generation of mobile communication systems that is widely adopted by vertically integrated industries. In addition to supporting millions of mobile subscribers, 5G will be used to interconnect machines, robots, sensors, etc. for the connected industries, which typically have quite demanding requirements in terms of the communication systems they use. Service-level specifications (SLSs) and the corresponding management mechanisms will play a key role in aligning the offerings of 5G communication service providers with the expectations of connected industries and clients. This applies especially to SLSs for private industrial networks (also called nonpublic networks or NPNs). For more detailed information on these, please consult Chapter 1 "Definitions" below. Forming part of a service-level agreement (SLA) between service customers and service providers, SLSs are a set of requirements for a 5G system used in an industrial environment. These can be performance requirements (e.g. fault tolerance and service availability features), measurement requirements and other specifications.

Using 5G for connected industries is new territory for both information and communications technology (ICT) and operational technology (OT) players. Although 5G has been deployed in many countries since 2019 for enhanced mobile broadband services, its use in commercial and industrial scenarios in nonpublic networks is only just starting to get off the ground. 5G has already matured enough to support industrial IoT (IIoT) use cases, but on the business level a number of basic issues still need to be clarified. They include, for instance, how to specify and negotiate contractual service requirements and how to make sure that these requirements are met during a 5G system's operational phase. A number of basic business-related questions are still open. All of these things require further study in order to present them more clearly and pave the way for practical implementation in industry.

This white paper aims to establish a common basis to facilitate communication on SLS among ICT and OT partners, especially in connection with industrial uses for 5G systems. 5G systems can be deployed in a variety of ways; the options include standalone nonpublic networks (SNPNs) and nonpublic networks (NPNs) that are integrated in public networks [20]. These can involve a wide variety of business models and roles. The service provider can be a 5G telecoms operator, a 5G equipment vendor, an end-to-end 5G solution provider, or the IT department of a company running a factory. Because service providers have different business models, their SLSs can also vary.

The key topics covered by this white paper are:

1. Defining SLSs
2. What a SLS looks like and how it is used across the system life cycle
3. Tools for generating SLSs

This white paper addresses both ICT and OT stakeholders.

About 5G-ACIA

The 5G Alliance for Connected Industries and Automation (5G-ACIA) was established to serve as the main global forum for addressing, discussing, and evaluating relevant technical, regulatory, and business aspects of 5G for the industrial domain. It embraces the entire ecosystem and all relevant stakeholders, which include but aren't limited to the operational technology industry (industrial automation companies, engineering companies, production system manufacturers, end users, etc.), the information and communication technology industry (chip manufacturers, network infrastructure vendors, mobile network operators, etc.), universities, government agencies, research facilities, and industry associations. 5G-ACIA's overarching goal is to promote the best possible use of Industrial 5G while maximizing the usefulness of 5G technology and 5G networks in the industrial domain. This includes ensuring that ongoing 5G standardization and regulatory activities adequately consider relevant interests and requirements and that new developments in 5G are effectively communicated to and understood by manufacturers.

1 Definitions

To improve understanding, a number of key terms are introduced and explained here at the beginning. For a more exhaustive list, please see Chapter 8.

Service-level agreement (SLA)

In the telecommunications sector, an SLA is defined in [1] as "an element of a formal, negotiated contract between two parties, viz., a service provider and a customer. It documents a shared understanding of all aspects of the service and the roles and responsibilities of both parties from service ordering to service termination. SLAs can include many aspects of a service, such as performance objectives, customer care procedures, billing arrangements, service provisioning requirements, etc." Basically, an SLS is an agreement between the provider and user of services that details the expected Quality of Service (QoS), responsibilities and so on.

In the context of 5G, network services tend to be associated with network slicing, which is an approach for running multiple logical customized networks on shared infrastructure. Network slicing is a deployment option for NPNs. [20] According to the GSM Association (GSMA), the customizable network capabilities include data speed, quality, latency, reliability, security, and services. These capabilities are always provided on the basis of an SLA concluded between a telecom operator and its business customers. [2]

According to [3], a good SLA helps service providers clearly define what is deliverable and service customers evaluate whether promised services have been provided as ordered.

Service-level specifications (SLSs)

In this document, we treat SLSs as the technical part of an SLA. Our discussion covers 5G services in an Industry 4.0 environment. The nontechnical components of an SLA include business terms (e.g. contractual penalties), legal consequences and so on.

This document extends the scope of the 3GPP SLS definition to also include Industrial 5G services.

Dependability and assurance

Dependability and assurance are both central concepts in OT. The ISO defines an item's dependability as the "ability to perform as and when required" [23]. This is a key capability of any automation system. Undependable automation systems can be unsafe or suffer from low productivity, to take two examples. It's important to stress that a dependable communication system is a prerequisite for achieving a reliable production system. For more information on communication system dependability, see [24]. The main attributes of dependability are reliability, availability, maintainability, safety, and integrity. The first three of these are especially important in the context of an SLS. An SLS can be regarded as a tool for documenting the level of dependability that a communication system's users need.

Dependability isn't a given; it requires careful planning and implementation. A user looking for a dependable communication system typically seeks assurances. These are statements that inspire confidence in its performance. Ideally, they are based on concrete evidence such as measurements of a 5G system's QoS.

2 Introduction

2.1 Background

In the information and communications technology (ICT) industry, SLA and SLS were well-understood concepts applied to previous generations of mobile communication systems that were mainly used for business to customer/consumer (B2C) types of services (e.g. voice calls, text messages and Web browsing). SLAs and SLSs are still commonly used at the business level between telecom operators and telecom equipment vendors to make sure that expectations are met (e.g. regarding equipment availability, mean time between repairs, customer support, etc.). A contract concluded between a telecommunications operator and a subscriber can be also considered to be an SLA, since it specifies the services provided to the subscriber (e.g. total voice call time or data volume per month, roaming parameters and so on).

The manufacturing sector has so far been characterized by communication technologies that are configured, deployed, and managed by individual manufacturers. When cellular services are used at all, it is only for applications that aren't critical to production. Manufacturers therefore have virtually no experience in specifying and applying SLSs for production-critical communication.

In the 5G age, mobile communication technology is ubiquitous in vertical industries. It is helping them find new, wireless ways to interconnect their machines and production lines. This is shifting the focus of provided mobile communication services from B2C to B2B, with the end users mainly taking the form of machines, sensors, robots and so on. Subscribers of B2C services have a much greater tolerance for service interruptions than machines. When mobile connectivity is poor, a human subscriber may simply try again later and do something else offline in the meantime. By contrast, an unplanned gap in service can cause a production line to grind to a complete halt, immediately slashing efficiency. Compounding the damage, the manufacturing operation often takes significantly longer to recover afterward than the outage itself lasted.

The manufacturing sector has its own QoS culture and language. For example, concepts such as dependability, assurance, and reliability can be defined very differently there. As a result, the SLAs and SLSs applied to B2B scenarios diverge significantly from those traditionally used in B2C contexts. To the best of our knowledge, there is no clear understanding of how to design SLSs that specifically target factories. The challenge is compounded by the fact that these SLSs can vary greatly between plants depending on both technical parameters such as the type of production, use cases, and brownfield technology and nontechnical aspects like business models, local laws and regulations and so on and so forth.

2.2 Current Service Provider Practices

Telecommunications operators use SLSs to specify the service requirements that their customers must meet. SLA requirements can vary across different types of services. For example, the SLA requirements for Ethernet services differ from those for satellite or VoIP services. Although the specified requirements can vary depending on the types of services involved and conditions in different regions and countries, most SLAs share a number of business-oriented criteria:

- Availability of network service conditions
- Repair time scales for different types of failures
- Consequences or penalties for service failures
- QoS (jitter, latency, packet drops, experience)
- Response time when a new request is issued
- Maximum delay in restoring service
- Scope of outage reporting
- Regular reporting of services
- Ability to measure the quality of services and monitor those responsible for measurements and reporting
- Implications denial of service attacks
- Network installation and maintenance (if applicable)
- Service response times for regular, critical, and informational requests
- Supporting processes, exclusions, renewals, limitations etc.

An SLA concluded between a service provider and a customer therefore typically specifies the scope of service, the service process, and statements on problem remedies and their implications.

2.3 Scope

This white paper illuminates the aspects that both OT and ICT players must consider before drawing up SLSs for factory and process automation use. The pertinent topics encompass SLS assurance and the role that SLSs play throughout the communication system lifecycle. The section on SLS assurance also discusses system features related to dependability. We will also introduce and discuss conceptual tools that can support SLS creation and enforcement. Where standardization is concerned, this white paper focuses on 3GPP Releases 16 and 17. Release 16 appeared in 2020, and Release 17 will tentatively arrive in September 2021.

In the following, we consider SLSs that are used to indicate 5G service execution status, performance, and interface requirements. We don't go into how to design a 5G system to meet a given requirement, instead addressing how to define and negotiate SLSs, especially for commercial deployment, and how to manage them throughout a 5G system's lifecycle. We also limit the discussion to SLSs used within the scope of 5G NPN.

2.4 Related Work

SLSs and SLAs were already studied long before 5G era within the scope of the 3rd Generation Partnership Project (3GPP). Back then, they could be formulated in terms of key quality indicators (KQIs) and key performance indicators (KPIs). For instance, [1] specifies KPIs for GSM, UMTS and so on, assigning them to various categories such as serviceability (including accessibility, retainability, and integrity) and availability (including reliability, maintainability, utilization, and mobility). These concepts were defined in ITU-T Recommendation E.800, which was published in September 2008 [34].

As we enter the 5G era, the focus of this standardization work is shifting to vertical industries. 3GPP SA1 has made a major contribution to defining use cases and requirements. It has supported factory and process automation [6][11] by collecting a wide range of use cases related to cyber-physical control applications and normative end-to-end service and network performance requirements. 3GPP RAN and SA have translated these requirements into 5G design features. For example, 3GPP SA5 has introduced end-to-end 5G key performance indicators from the management and orchestration perspectives [7]. It has introduced a novel approval approach, based on the NWDAF (Network Data Analytics Function),[32] that has the ability to leverage KPIs (and the corresponding sustainability mechanisms) for providing data analysis capabilities from the 5G core network.

Vertical industry needs were also analyzed by the Global Mobile Suppliers Association (GSA), which proposed a three-level model spanning performance, functional, and operational requirements [4]. All of this constitutes a major departure from the legacy mobile communication business prior to 5G, for which mainly performance-focused SLSs were formulated. Functional requirements have to do with network capabilities (e.g. positioning, device management, etc.) that OT partners can use. Operational requirements have to do with a system's ability to manage and run communication services, such as QoS monitoring, slice management, and reporting.

GSMA published a report on the "GSMA Generic Slicing Template (GST)" [8] comprising a set of attributes for characterizing network slices. Network slicing is a key feature of the 5G system architecture that enables tailored connectivity and data processing for specific types of applications. GST is a generic tool and not tied to any particular network deployment or industry use case. But it is a good starting point for discussing service-level specifications for industry use cases from the telecom operator and public service network viewpoints.

Last but not least, 5G-ACIA itself has published extensively on use cases and requirements for 5G-connected industries, for instance in various white papers [5],[12],[17].

3 SLS for Connected Industries

As already mentioned, the SLSs used for B2B scenarios are very different from those in traditional B2C scenarios. Above all, they focus strongly on ensuring service. This has two implications for SLSs:

1. Vertical use cases vary greatly. Different use cases call for very different kinds of communication services, which need to be described by SLSs using different attributes.
2. Due to the special nature of vertical use cases, novel attributes are emerging that weren't present in conventional B2C-type SLSs. These can be more than agreements on connectivity performance (i.e. availability, latency and so on), also including operational and management specifications to ensure the active involvement of customers.

It's therefore essential to understand service-level components for 5G-enabled industrial networks that involve non-public network (NPN) services. Factories and NPN services provided to businesses can be quite complex. Industrial networks typically have an IT domain and a production domain, with the latter including services for secure in-building manufacturing facilities, asset tracking, shipping and so on. Table 1 shows examples of ways in which many of the common requirements for industrial network services are met:

Table 1: Common requirements of industrial network services

Requirements	Examples
Types of services	• Communication service
Managed service components	• Ownership, relationship, API, software, hardware, certification etc. • Reports and their frequency
Service availability	• Platforms (breakdown of availability requirements into different technical components) • Service components (portals, device registrations, APIs, device key generation, storage and retrieval of certificates, keys, etc.) • Spectrum availability (type of spectrum, e.g. licensed or unlicensed, frequency of availability and dynamicity[1], scope of spectrum for public network if needed) • Managed service components (latency, frequency, time synchronicity, interoperability, cell coverage capacity, reliability, security) • Fault tolerance (active standby mode, hot standby, running parallel applications, digital twins on a cloud platforms, edge services to assure reliability) • Optional/backup connections to a public land mobile network (PLMN) service for voice and data, e.g. especially for standalone NPN (SNPN) [20]
Responsibilities shared by OT and ICT	• Roles and responsibilities (who provides which services) • Components (functions, software, hardware, API, database, storage, networks) • API, certificate authorities, credentials, shared keys (encryption), device registration and management • Access policies (who grants access and when) • QoS (implications for 5GS in an OT environment) and exposed network capabilities [12] • Tolerance level of individual networks, platforms and services • Failure recovery time for each service

[1] Spectrum sharing is becoming available in some countries, including the USA. These spectra typically have tiers of access and incumbents that enjoy preferential access for short periods of time (e.g. a few hours or days).

4 SLS Assurances

One of manufacturers' main concerns is their factories' productivity. One commonly used performance benchmark is factory utilization: how many hours per year can or does a factory produce? Manufacturers usually strive to maximize this value, in some cases even producing 24/7. A reliable communication system is an essential prerequisite for this, and meeting it is a key part of SLSs for nonpublic 5G networks used to automate factories and processes. Since it takes effort to make communication systems highly dependable, and unforeseen events can detract from their performance, manufacturers typically implement processes and mechanisms that will maximize their systems' reliability and uptime.

These processes and mechanisms give rise to statements designed to inspire confidence in, for instance, those who use communication media [25], [26]. The evidence provided to reassure them can be obtained by various means, one of which is QoS monitoring.

Assurances are especially important for use cases related to factory and process automation. This is because communication lapses can make a dent in manufacturers' revenues. Their impact can be great even if they are brief: the harm can be greatly compounded by the need to reboot production systems afterward, which can be a time-consuming process. The loss of connectivity can even be interpreted as an intrusion, prompting production cells to go into a safe mode. Multiple checks, including visual ones, are then required before it can resume operating.

The terms of the SLS therefore need to be seamlessly complied with while a 5G-based system is operating. This is a much thornier challenge than for wired networks, since wireless connectivity can be affected by numerous factors including electromagnetic interference, automatic guided vehicles (AGVs), robots, etc. The 5G system itself therefore integrates many features that are designed to improve connectivity; these are explained below.

4.1 System Considerations for Formulating SLSs

The 5G system embraces multiple technical domains that include radio access, core, and transport networks as well as network management domains. Formulating SLSs therefore calls for a thorough, end-to-end system perspective that isn't limited to radio access. Some system aspects[2] related to dependability are discussed in this section.

4.1.1 Cloud-Native Architecture and Microservice Decomposition for Operational Agility

By design, the 5G core network is native to the cloud. Cloud architectures can be leveraged to build a flexible, simplified, more reliable core network. Key enabling technologies such as stateless design, cross-data-center disaster recovery, container technology, and service-based frameworks can be leveraged to build a robust 5G core. Reliability can be additionally enhanced by an advanced redundancy mechanism for service processing units. This differs dramatically from the monolithic approach traditionally taken by the telco industry. A suitable monitoring tool for cloud-native services is also important.

4.1.2 Network Slicing

Network slicing, one of the key features of 5G system architecture design, can be used to provide an NPN that is hosted by a public network [20]. This network architecture can make a system more dynamic and flexible and therefore especially well-suited for customers who don't want to invest in 5G infrastructure because they only require deployment for a temporary NPN, or else deal with quickly changing use cases or diversified 5G utilization scenarios.

A network slice is a specialized isolated end-to-end network with its own functionality. Network slicing as a service can be used to support greater differentiation of network services.

[2] This is not a complete 5G feature list. There may be other features related to SLS assurances that are not discussed here.

By supporting flexible, customized design of functions, isolation mechanisms, and operation and management tools, it is suited for providing dedicated logical networks hosted on a shared infrastructure. A 5G system can have a different, dedicated SLS for each network slice. And within each slice, SLSs (especially those that specify demanding requirements) can be met by slice-specific functions and dedicated resources, e.g. logical or physical isolation mechanisms to ensure reliability.

3GPP currently defines four types of slices: enhanced mobile broadband (eMBB), ultrareliable low latency communication (URLLC), massive machine-type communication (mMTC), and vehicle-to-everything (V2X) communication [21]. The corresponding management, orchestration, and provision services are covered in [30]. GSMA is addressing the business angle by defining slice templates that specify customer requirements [8].

Many mechanisms have been defined for network slicing in the context of NPNs, mainly to increase confidence in services:

- Slice creation and provision of responsibilities and launching
- Implications of the failure of slices to work properly
- Slice monitoring options and reporting
- High slice availability etc.

Slicing of NPNs provides a variety of deployment options. For example, the user plane functions can be kept local in NPNs (e.g. the OT campus) while the control plane functions are provided by the public network (e.g. in MNO offices). In a configuration of this kind, responsibilities can be shared by different business entities; for example, an MNO could be responsible for orchestrating, creating, and maintaining slices while the OT runs on the user plane. Signaling and some credentials can be carried out and stored at shared locations. Monitoring can also be carried out either centrally or remotely. In this scenario, the considerations for slicing are similar to the ones for isolated NPN scenarios, but the responsibilities and monitoring permissions can diverge and be negotiated by the ICT and OT. This may require the two organizations to share API functions and conclude business agreements on functional responsibilities.

4.1.3 Redundancy

Redundancy, in other words duplication of a system's crucial components, is frequently implemented to improve system availability, performance, and/or reliability. This approach can be taken regardless of a 5G system's design, its physical equipment, or the virtual resources used to deploy it. Backup components can be added to take over from the main components in case they fail, or else be natively embedded, e.g. to introduce connectivity via redundant user plane paths to support URLLC traffic [21].

Two main types of redundancy are used: dynamic redundancy and static redundancy [18].

- With dynamic redundancy, the redundant links only come into play if the main working link fails. These methods incur lower costs in terms of resource use, network operation, and management overhead, but they involve a nonzero switchover time – a certain amount of lag has to be taken in stride. In order for these methods to be worthwhile and avoid the need to take emergency action, the recovery time must be shorter than the survival time. This may not be suitable for industrial use cases that require very high communication service availability but are characterized by short survival times.
- Static redundancy methods concurrently send duplicated information over the redundant links. They therefore provide high availability and seamless switchovers, but cost more in terms of resource use (e.g. radio or network resources) and network operation and management. When implementing end-to-end dual connectivity, moreover, spectrum use may also be a limiting factor; since it is a scarce resource, reserving twice as much of it can significantly impact system design.

In any case, as indicated in TS 23.501[21], ways to use duplicated paths for traffic delivery are beyond the scope of 3GPP. It is up to industrial applications or upper-layer protocols to manage the replicated sections.

4.2 System Aspects That Impact Assurance

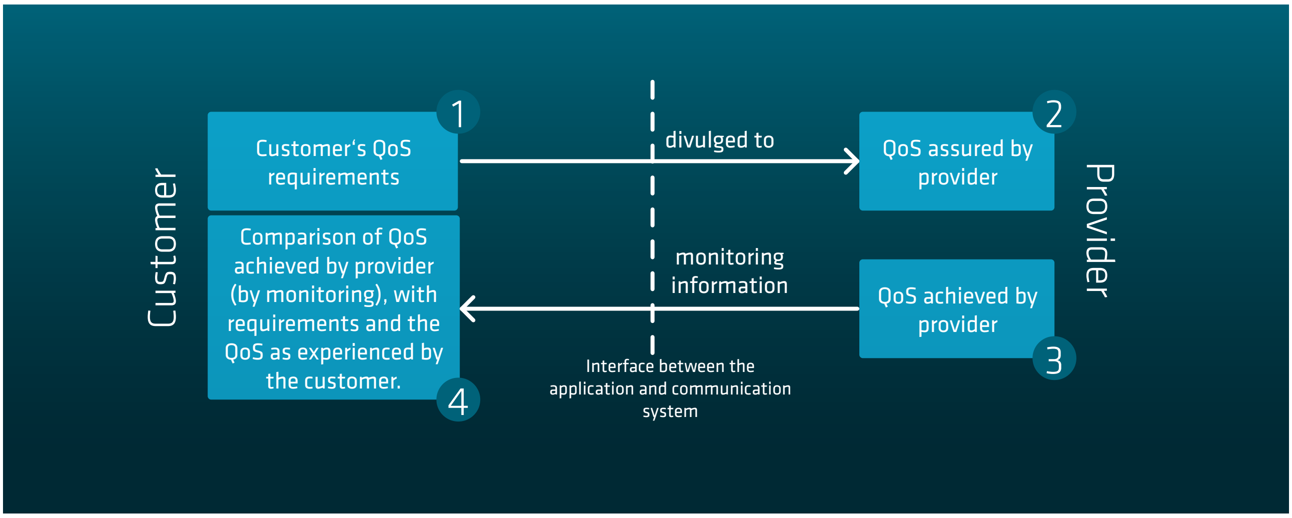
4.2.1 QoS Monitoring

QoS monitoring functions can be used in the 5G system for SLS assurance purposes. This involves four main steps as shown in Figure 1: (1) the customer specifies the expected level of quality, (2) the service provider offers it to the customer, (3) the expected level of quality is achieved and provided to the customer, and (4) the customer evaluates the quality delivered by the provider and its own experience of that quality.

QoS monitoring can be carried out in individual technical domains (e.g. radio access networks, core networks, transport networks, or other non-5G domains). The 5G service provider can add end-to-end QoS monitoring to the 5G domain. The 5G network itself is integrated in a "hybrid" factory communication system (such as WLAN/Wi-Fi or Industrial Ethernet) that may already include packet inspection. In this scenario, the service customer and service provider could both monitor the QoS, but on different levels.

Where QoS monitoring is concerned, another important aspect is that SLSs don't only cover forwarding-plane services (such as connectivity and packets), but also control-plane services (for instance, how many user equipments (UEs) are allowed to poll which QoS information and how often) as well as other non-communication services, such as localization services.

Figure 1: QoS assurance using QoS monitoring information [11]



4.2.2 Network Diagnostics

Network diagnostics helps find, analyze, and identify problems within a network. It relies on data collected on physical connections, logical links, and subnetworks [11]. On this basis, it can provide clear explanations of current and potential problems. It can suggest corrective actions that can be taken either manually by customers or automatically and inform the customers about the outcome. Network diagnostics can deal with faults either reactively or proactively. When a failure happens, it's vital for OT customers to know whether it has been caused by an industrial application or a communication system. Importantly, diagnostics isn't only about informing OT customers about a problem. It must also include a proactive approach integrated in the 5G system for responding to diagnosed failures and letting customers know how long it will take to deal with problems.

4.2.3 Prediction-Based Assurance

SLS prediction mechanisms can be used to anticipate SLSs (such as system availability and reliability) in order to take required action for SLS assurance (such as resource scaling, instantiation of network functions, and altering the policy on monitoring of SLS attributes). SLS prediction mechanisms should be considered if conventional SLS monitoring and runtime adjustments aren't adequate for ensuring that service performance requirements will be consistently met during servicing and system operation phases. A 5G system's SLS prediction mechanisms can be executed on the network management and control planes, using monitoring data and predictive data analyses for the system and associated services (e.g. networks and network slices).

Where predictive data analysis for 5G systems and services is concerned, 3GPP defines a network data analytics function (NWDAF) [32] and a management data analytics service (MDAS) [33]. The NWDAF is defined as a control plane network function for generating analytical information, including predictions and probabilities expressing the level of confidence in them (e.g. network slice load predictions, network performance predictions, and service experience predictions). The MDAS is defined on the management plane and analyzes performance management and fault management data to support and meet a wide variety of services and requirements. For example, fault management data analytics services can be used to predict and prevent network failures on the domain level (e.g. radio access, core network, network slice subnet) and PLMN level.

Key enabling technologies such as artificial intelligence and machine learning can be used to achieve efficient, accurate, and reliable predictions for SLS assurance. There is an ongoing discussion on this within 3GPP.

4.2.4 Closed-Loop SLS Assurance

3GPP has recently started looking into closed-loop SLS assurance [29]. A work item has been defined for investigating it from the network management perspective. The idea is to shed light on how machine learning algorithms might be deployed for providing cross-domain automated management services. A number of possible technical solutions for this are being examined, including new use cases and requirements, data models and management services, and ways of applying machine learning models to provide closed-loop SLS assurance. The solutions that pass muster will form part of the upcoming Release 17.

4.3 Accountability

Accountability is an important aspect of SLS assurance. It is an aspect of the responsibility that is associated with designing, deploying, maintaining, and operating a 5G system. While products, services, and contexts can influence the choice of risk management approaches, in order for a contract to reliably ensure business continuity and accountability it must clearly define and assign roles.

In the context of Industry 4.0 and the adoption of 5G technology for smart manufacturing, the first and most important step is to identify the relationship between business goals and 5G service models. The 5G technologies now specified in 3GPP already offer a range of deployment choices for supporting industrial use cases. In the context of 3GPP, they are referred to as standalone NPN and NPN in conjunction with public networks (with the latter differentiated further into shared RAN, shared RAN and control plane, and NPN hosted by a public network). The deployment options are detailed in a 5G-ACIA white paper [20]. Different deployment models can be associated with a variety of business models and roles, all of which also have implications for accountability.

This paper doesn't discuss business models in any greater detail, but it is worthwhile to consider the implications of the differences among these models for commissioning, including the procurement and contract management processes. They assign involved parties to different roles that include those of business owner, commissioner, manufacturer, solution supplier, system integrator, and service provider. The list of potential roles goes on. The activities also include designing 5G infrastructure, implementation and rollout, upgrading and maintenance of deployed infrastructure, integration and migration of business applications and processes, maintaining 5G services, documentation and reporting, and change management.

Where commissioning and infrastructure management services are concerned, appropriate assignment of accountability would focus on aspects such as performance management, capacity management, incident management, response times, targeted recovery times, service-level reporting, IT domain and tooling, infrastructure and service life cycle management, service and process upgrading, assets and configuration management, storage and backup management, continuous optimization, security including physical and cyber security and everything in between, business continuity goals, governance, and compliance including certification.

With the new functional and management capabilities in 5G technology, value could be added by outsourcing these services. Accountability should be assigned to ensure the delivery and approval of activities such as service requirements negotiation, SLS identification, network resource planning, service provision, optimization, delivery of communication and capability exposure services, coordination of domain management, service quality of experience collection, service-level monitoring, SLS assurance, service-level reporting, and incident management.

In order to properly assign roles, the SLA must be clearly understandable in terms of the contract management process and governance mechanisms. On the practical level, a number of approaches are available for assigning accountability. They include a responsibility assignment matrix (also known as RACI matrix),[22] which has been used widely in some other industries and has been adding value in a variety of contractual approaches.

- Responsible: Those who do the actual work involved in completing a task.
- Accountable: The person or persons who ultimately make decisions and give approval. They are answerable for the correct and thorough completion of a task or deliverable.
- Consulted: Those whose opinions are sought before an action is taken; typically they are subject-matter or domain experts.
- Informed: Those who are kept up to date on actions taken or decisions made. Normally there is only one-way communication with these.

No matter which methodology is chosen, the suggestion is to clearly assign roles in the contract. The same statement applies to role assignment in disaster and incident situations, which may call for backup capabilities involving project teams or taskforces.

To sum up, it is possible to assign more than one role to the same company if the commissioned products or services are different. This implies that the industry needs to reassess how the roles of business partners have been perceived and understood in the past from the new perspective of 5G adoption models.

5 SLSs During the Communication System Lifecycle

General SLSs are provided by the service provider and the details filled in by the customer. During the initial phase, they serve as a contract based on a shared understanding and expectations on the services to be provided. They also serve as a guide for checking whether the service provider's promises are kept under the specified conditions. SLSs can be used throughout a 5G system's entire lifecycle and apply to all of the services provided during the pre-deployment, deployment, and system operation phases.

Pre-deployment phase:

- Definition of SLSs:
  The service provider defines and formulates a SLS template (covering, for example, performance, and functional and operational attributes).

- Requirement and use case analysis:
  The customer's service requirements and scope are identified by analyzing planned use cases, and the results applied to generate inputs for the SLS template. As far as possible, use cases with similar service requirements should be grouped together. Communication protocol requirements should be addressed, for example clarifying which traffic will pass through each layer and whether the 5G system will take the form of a synchronized time-sensitive networking (TSN) bridge.

  Industrial customers should be able to specify monitoring-related reporting requirements based on their own use cases, which can include the reporting period (e.g. second, minute, hour, day, week, month), reporting object (e.g. operation level, network service level, cell level, slicing level), and reporting value type (e.g. average, maximum, minimum). Examples of monitoring parameters are provided in Appendix C of reference [12]. It should be possible to report alarm notifications and fault analyses (in case failures occur in variant technical domains). Relevant alarms may trigger corresponding actions for resolving problems (e.g. pinpointing errors or creating taskforces for dealing with emergency situations).

  It's important to clarify how the high-level SLS diagram should be interpreted in actual practice. For instance, UEs as part of the experienced end-to-end quality should be discussed in the SLS negotiation phase. To avoid a mismatch between the 5G system and UEs (e.g. UEs that don't support all of the features needed for the use cases), the service provider may specify which kinds of UEs may and may not be used.

  System operation and maintenance requirements and the corresponding responsibilities must also be discussed and clarified. For instance, whether the service provider will provide the customer with 24/7 production maintenance support (i.e. also at night) or the customer's production staff will be responsible for managing the 5G network in the event of an emergency. The customer must also specify the kinds of interfaces and access rights it requires to perform operational and maintenance tasks.

- Negotiation and contract:
  The agreed SLSs should be based on discussion and negotiation between the service provider and the customer and take the form of a signed contract. It's especially important for them to agree on a policy for monitoring SLS attributes.

- System design, estimation of capabilities, and deployment planning:
  The industry use cases requirements specified by SLSs have to be translated into specifications for network functions, resources and capabilities and the corresponding configurations for network operation and management. From the operator perspective, based on the defined SLSs and regional regulations and conditions (e.g. spectrum availability), this means creating a deployment model (e.g. SNPN or PNI-NPN), network object models (e.g. radio access, core, and transport), attribute models (capacity, coverage, latency, reliability etc.), failure risk models and so on. This can be done using simulation tools or an intent-driven management system (see TS 28.312 [31] and TR 28.812 [35]).

  Service configuration time is another crucial component of SLSs. The service provision plan should specify configuration methods and a timeline for adding new service components and overall deployment.

- Testing:
  SLS attributes should be verified using clearly defined testing methods and the test results accepted by the service customer. Previous work done on performance testing within the scope of 5G-ACIA sheds light on this topic [28]. However, test result acceptance for industrial use cases with stringent requirements is a challenging issue and needs to be thoroughly analyzed.

Deployment phase:

- Network and service deployment
  Deployment of the 5G infrastructure (including hardware and software) in accordance with the plans and setup or instantiation of the corresponding network services.

- Service configuration
  Configuration of the 5G system (e.g. resources, network functions, and interfaces) based on the deployment model. This stage also includes configuring relevant assurance mechanisms, such as QoS monitoring and APIs for network diagnosis. Diagnostic information is helpful for the deployment and commissioning phases. Baseline reports are typically part of the SLA, so the service provider should provide them to the customer after deployment has been successfully concluded.

System operation phase:

- Monitoring for assurance
  Monitoring of SLS attributes is essential for verifying fulfilment of the agreement between the service provider and service customer and for tracking down faults. 5G systems should integrate appropriate monitoring mechanisms (network functions), APIs [12], and relevant services (e.g. dashboard services) across the entire infrastructure, which may include multiple technical domains (e.g. radio access, core, and transport networks). The entire 5G system can be monitored 24/7. Features of this kind directly improve customers' perception of and satisfaction with the provided services.

  It should therefore be possible to:
  - Monitor both overall system performance and individual technical domains (e.g. radio coverage, connectivity etc.)
  - Monitor the system's operational status such as startup or shutdown and the status of various technical domains like the core and radio access networks
  - Monitor firmware updates, e.g. their execution status
  - Monitor individual communication services
  - Monitor industrial use cases, e.g. device-to-device, device-to-machine, controller-to-machine etc.

  Monitoring mechanisms may make use of computer vision technologies, for instance video cameras for more accurate localization.

- Operation and maintenance
  Overall system operation and maintenance, and especially the service provider's responses to emergencies and failures, must comply with the SLSs for preventing and rapidly troubleshooting any production standstills.

- Enforcement
  Monitoring of SLS attributes is essential for SLS enforcement and compliance. The 5G system must enforce the agreed SLSs. In the event of violations, the service provider can be required to pay penalties.

- Runtime adjustments
  SLS fulfilment must be managed based on runtime information, e.g. dynamically adjusting available resources and performing proactive fault management and other steps to prevent SLS violations.

In every phase of the communication system lifecycle, it's essential for the responsibilities and roles to be clearly defined. This applies not only to the service provider and customer, but also to dependencies and relationships within the customer organization (such as its IT and OT departments). For example, the customer may reconfigure some parameters after the service provider has deployed and initiated operation of the 5G system. For cases like this, it's vital to stipulate who is responsible for testing and acceptance (to make sure that the reconfiguration is correctly performed) and who will take responsibility for any problems or faults that directly or indirectly result from the reconfiguration. The use of these so-called responsibility matrices is a totally new practice for both the ICT and the OT partner and there is a need for additional thorough analysis.

An SLS can also define the lifetime of a service and the relevant terms for terminating it.

6 Conceptual Tools

6.1 SLS template

SLSs for factory and process automation should specify the OT partner's requirements, which then serve as input for designing the 5G system. It can also be used as a guide for evaluating and accepting performance during deployment and operation of the system. A well-defined SLS should be meaningful, understandable, achievable, measurable, and mutually acceptable [9].

Depending on the provided services and negotiations between the service provider and customer, SLSs may vary greatly. One conceptual tool that could be useful for OT is a SLS template with the essential attributes for planning a 5G system and associated services. For communicating these basic attributes to a 5G service provider, an initial 5G deployment or service provision plan could be generated (especially for radio resource planning and key system features).

Based on these attributes, it's possible to specify many other customized attributes that can vary from one customer to another. For instance, an OT partner may request 24/7 customer support and a 10-minute response time as built-in attributes, but features of this kind don't influence the underlying 5G system design. This document focuses on fundamental attributes for associated industries and automation.

SLSs address both system-level and service-level attributes. System-level attributes are the requirements for the overall 5G infrastructure, while service-level attributes apply to the user equipment (UE) level (see clause C.1 in [6]). Tables 2 and 3 present SLS templates with the basic attributes for a 5G network and communication services. Multiple service-level templates may be needed to capture all of the requirements if a 5G system is expected to support widely diverging use cases for a customer.

Table 2: Proposed SLS template for system-level attributes

	Attribute	Requirement	Influences quantity	Discussion	Reference
System level	System availability	X		The entire 5G system is ready and able to provide services within an agreed area and timeframe under specified conditions. This attribute may be the result of the aggregated value provided by involved hardware and software components. It may also be inferred from accessibility (the radio bearer establishment success rate) and retainability (the radio bearer abnormal release rate).	IEC 61907 [10] 3GPP [11]
	Cell availability	X		The fraction of time in which a cell is available.	3GPP TS 32.410 [1]
	Service area		X	The geographical region within which a 3GPP communication service is available. The service area can be indoors or outdoors.	3GPP TS 22.261 [11]
	QoS monitoring	X		The ability to assess information pertaining to network operation and communication services, which is essential for QoS assurance purposes such as fault localization and management. This metric is also referred to as sustainability. It may also include sub-attributes such as monitored content, SNR, and device handover rate. The annex to another 5G-ACIA white paper [12] lists some connectivity-related device parameters that a factory operator expects of a 5G network. These attributes are available to the factory operator from a separate communication service. Whether or not they are also available to the communication service provider and/or mobile network operator is a matter of agreement.	5G-ACIA [12], 3GPP TS 22.261 [11]

In connection with service, the 5G QoS model is based on the concept of QoS flow, which is the lowest-level granularity in a PDU session [21]. QoS flows have different priority levels. Whether or not QoS flows comply with a SLS depends on the planned system capacity and how that capacity is used by higher-priority QoS flows.

It's important to stress that QoS assurance is always related to resource planning and management. Admission control (e.g. for public networks) tends to be stochastic, i.e. it is characterized by dynamic variations in traffic flows, and system resources typically aren't planned to provide enough capacity to handle peak throughput for all allowed QoS flows. This is very different from industrial scenarios, which are characterized by fewer random factors. For instance, the number of production lines is relatively fixed and AGVs move in defined patterns. This must be considered for planning resources.

Note that it is necessary to document not only user requirements but also relevant parameters such as the service area, transfer intervals, and the speed at which UEs will move. Especially when the 5G system must meet challenging requirements, it is vital to know these values.

Table 3: Proposed SLS template for system-level attributes

	Attribute	Requirement	Influences quantity	Discussion	Reference
System level	Communication service availability	X		Share of time during which the end-to-end communication service is provided based on a QoS agreement, divided by the amount of time during which the system is expected to deliver end-to-end service as specified within a defined area.	3GPP TS 22.261 [11]
	Communication service reliability	X		Ability of the communication service to perform as required under defined conditions in a given time interval. The mean time between failures is one of the indicators typically used to express the reliability of communication service. It expresses the mean amount of time during which the communication service is available without any interruptions.	3GPP TS 22.261 [11]
	End-to-end latency	X		The time that it takes to convey a given piece of information from a source to a destination, measured at the communication interface, from the moment it is transmitted by the source until the moment when it is successfully received at the destination.	3GPP TS 22.261 [11]
	Transfer interval		X	The time that passes between two consecutive transfers of application data from an application via the service interface to a 3GPP system	IEC 62657-2 [13]
	Survival time		X	The time that an application using a communication service can continue without an anticipated message. This parameter is typically applied to periodic communication services.	3GPP TS 22.261 [11]
	Message size		X	The user data length indicates the (maximum) size of a user data packet delivered by an application to the entry point of a communication system or from the exit point of the communication system to the application. This parameter is typically applied to periodic communication services.	3GPP TS 22.261 [11]
	User-experienced data rate	X		The minimum data rate required to achieve an experience of sufficient quality, except for broadcast-type service scenarios in which the given value is the required maximum. Typical metric: target value (bit/s). This parameter is typically applied to aperiodic communication services.	ITU-T I.113, 3GPP TS 22.261 [11]
	Mobility	X		5G will support UEs with a range of mobility management needs.	3GPP TS 22.261 [11]

	Attribute	Requirement	Influences quantity	Discussion	Reference
System level	Positioning service	X		This includes sub-attributes such as: Positioning service availability: the share of time during which the positioning service delivers required position-related data while meeting performance requirements, divided by the amount of time the system is expected to deliver the positioning service according to specifications in the targeted service area. Positioning service latency: the time that elapses between an event that triggers the determination of position-related data and when the position-related data become available at the system interface. Positioning serv ice accuracy (95 % confidence level)	3GPP TS 22.261 [11]
	User plane transport protocol	X		IP or Ethernet	-
	Clock synchronization	X		Also called time synchronization precision, it is defined between a sync master and a sync device. Precision: the maximum allowed time offset within a synchronization domain	3GPP TS 22.104 [6]

To reduce the complexity of management without addressing the details of the underlying network infrastructure, 3GPP introduced an intent-driven management concept [31]. An SLS template of this kind can be regarded as an intent. A service customer's intent expresses what they want to do even if they don't know how to do it, like the details of managing and operating a communication service.

6.2 Example SLS

This section presents an example to illustrate use of the SLS template proposed above for an OT customer that wants to deploy a 5G system for two shopfloor use cases, one involving AGVs and the other motion control. They are described in greater detail in sections 7.2.1 and 7.2.2 below. Table 4 lists the overall system requirements.

Table 4: Example system level

	Attribute	Discussion
System level	Network availability	99.9 %
	Cell availability	99.99 %
	Service area	Indoor on workshop floor as well as raw material storage area
	QoS monitoring	Yes: system and service-level KPI monitoring (e.g. latency, user experienced data rate, handover rate), monitoring interval: 1 second

6.2.1 Automated Guided Vehicles (AGV) / Mobile Robots

Background information:

An AGV has its own application-layer fault tolerance mechanism. For instance, while an AGV is operating it sends a status packet to the control system every 100 ms. If it doesn't receive a response packet during 500 consecutive milliseconds, it sends an AGV disconnection alarm. While an AGV is idling, it sends a status packet once every second. If a response packet isn't received during five consecutive seconds, it is assumed that the connection to the AGV has been lost.

If an AGV (e.g. in logistics and warehousing scenarios) can no longer operate because the communication service has failed, this can have the following consequences:

- The AGV shuts down and stops carrying materials. This makes it impossible to shut down the task performed by the AGV, which in a worst-case scenario may even cause production to grind to a halt.
- The AGV traffic control system concludes that the AGV is in an abnormal state, possibly prompting it to close down the area where the AGV is assumed to be (e.g. based on the last information received) and prevent any other AGVs from passing through it. Unless this area is temporarily released from the traffic control system, the congestion can back up further and affect more AGVs. In certain implementations, the control system may command all AGVs in the factory to stop moving.

Table 5: Example SLS for the AGV use case

	Attribute	Discussion
System level	Communication service availability	99.9999 %
	Communication service reliability	1 year
	End-to-end Latency	100 ms
	Transfer interval	100 ms
	Survival time	500 ms
	Message size	500 bytes
	Mobility	4 km/hour
	Positioning service	Yes, accuracy: 1 m
	User plane protocol	IP

6.2.2 Motion Control

Background information:

A motion control system is responsible for controlling moving and/or rotating parts of machines in a well-defined manner, for example in printing presses, machine tools, or packaging machines [6]. Such a use case poses very challenging requirements for system performance in terms of latency, reliability, and determinism. Due to stringent latency requirements, the industrial application layer may not be able to tolerate any loss of packets. The failure of motion-control-type use cases normally results in the entire production line being shut down and reduces efficiency.

Table 6 shows an example SLS for this use case.

Table 6: Example SLS for the motion control use case

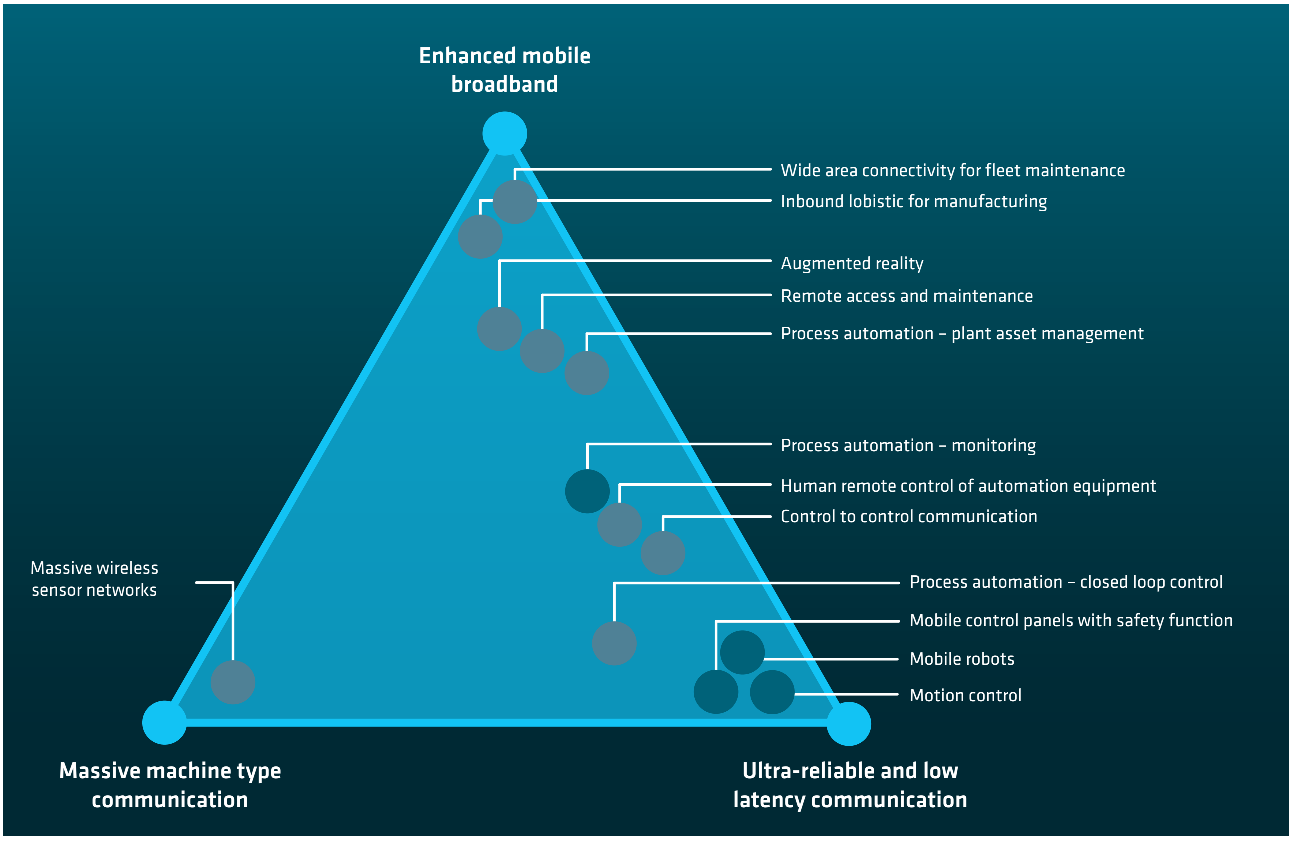
	Attribute	Discussion
System level	Communication service availability	99.9999 %
	Communication service reliability	10 years
	End-to-end latency	1 ms
	Transfer interval	1 ms
	Survival time	0 ms
	Message size	64 bytes
	Positioning service	No
	User plane protocol	TSN
	Time synchronization precision	900 ns

6.3 Categorization of Attributes

Since there is a wide variety of possible industrial use cases, the recommendation is to group together those that have similar service requirements or features so that they can use the same SLS. This will reduce the complexity and work of defining and negotiating them.

In early work carried out by 5G-ACIA to analyze use cases and performance,[27] visual aids like the example shown in Figure 2 below were proposed. This was the first attempt to group industrial use cases according to the service features defined by 3GPP.

Figure 2: Overview of selected industrial use cases, arranged according to their basic service requirements [27]



This conceptual tool can help stakeholders to group use cases, formulate machine-friendly descriptions of requirements, and influence quantities. A communication service provider's potential customers may be from different industries, and each industry may have very different use cases. It would be possible to discuss all possible attributes with customers one by one, but this approach isn't scalable. It could make sense to categorize the attributes defined in a SLS by assigning them to a handful of meaningfully defined, easily managed levels. Table 7 presents some example categorization definitions for different attributes.

Table 7: Attribute value categorization examples

	Level 1	Level 2	Level 3	Level 4	Level 5
Minimum network availability	99 %	99.9 %	99.99 %	99.999 %	> 99.9999 %
Minimum communication service availability	99.9 %	99.99 %	99.999 %	99.9999 %	> 99.99999 %
Minimum communication service reliability	1 week	1 year	5 years	10 years	> 10 years
Maximum end-to-end latency in ms	50 to 100	20 to 50	10 to 20	5 to 10	< 5
User-experienced data rate in Mbit/s	< 100	100 to 200	200 to 500	500 to 1000	> 1000
Mobility in km/hour	Stationary	0 to 5	5 to 30	30 to 100	> 100
Minimum position accuracy in m	3 to10	1 to 3	0.3 to 1	0.1 to 0.3	< 0.1

Service providers could use categorized attributes to additionally generalize the services provided for different types of use cases, for example as shown in Table 8. Service providers could also provide predefined service templates with recommended values that customers can directly choose. In case there are no suitable predefined services, customers could also describe their own requirements by indicating the corresponding attribute levels.

Table 8: Service definition example based on categorized attributes

Services		Minimum network availability	Minimum communication service availability	Minimum communication service reliability	Maximum end-to-end latency	User-experienced data rate	Minimum position accuracy	...
Predefined services	Type A (NPN with high availability)	L4	L2	L2	L1	L1	-	...
	Type B (Large bandwidth and good delay experience)	L2	L2	L2	L2	L4	-	...
	Type C (high reliability, low latency and positioning)	L4	L4	L2	L3	L1	L3	...
	Type D (Extremely reliable and ultra-low latency, together with high precision positioning)	L5	L5	L3	L5	L1	L4	...
Customized service	Service 1	..	..	..	..	..	..	...
	Service 2	..	..	..	..	..	..	...

Note: The last column of Table 8 indicates that other attributes may also be involved.

7 Summary and Outlook

5G is opening up enormous new opportunities for connected industries. 3GPP Releases 16 and 17 have gradually enhanced the 5G system's industrial IoT capabilities, thus bringing us a step closer to the commercial deployment of 5G and especially for use cases related to factory and process automation. At this stage, some essential practical questions urgently need to be answered. They include how to define and negotiate SLSs in commercial contracts and how to meet the promises made in them throughout a 5G system's lifecycle. This report is the first attempt to answer these questions.

However, this is just the starting point for discussing SLSs for connected industries. Many aspects still to be additionally clarified and understood better in future work, for instance:

- Clear, mature SLS acceptance criteria: testing during the pre-deployment phase may only reveal equipment and network capabilities without directly addressing a system's actual real-life performance.
- Comprehensive service monitoring methods: understanding of the QoS monitoring gaps between what has been defined in 3GPP and vertical industry demands and how to additionally enhance the monitoring mechanisms.
- A clearly defined O&M responsibility matrix: responsibility should be broken down for the technical and business domains, based on the deployment model and associated business model in each case.
- What other conceptual models could help practitioners generate and execute SLSs?
- The scope of 3GPP and the features defined in its specifications are steadily evolving with each release. Many topics related to SLS will also continue to develop, like prediction-based assurances and closed-loop SLS assurances. It's important to apply SLS-related requirements from vertical industries to 3GPP in a timely manner so they can be tackled in Release 18 and beyond.

8 Abbreviations

3GPP
The 3rd Generation Partnership Project (3GPP) is a collaborative project that brings together standardization organizations from around the world to create globally accepted specifications for mobile networks. As its name implies, it was first created to establish such specifications for the third generation (3G) of mobile communication systems. It has continued its work for subsequent generations, including the one considered here, the fifth generation (5G).

5G
Fifth generation technology standard for cellular networks (often also used to refer to technology adhering to this standard)

5G-ACIA
5G Alliance for Connected Industries and Automation

AGV
Automated guided vehicle

B2B
Business to business

B2C
Business to customer/consumer

GSMA
The GSM Association is an industry organization that represents the interests of mobile network operators worldwide.

GSA
Global Mobile Suppliers Association

GST
Generic slicing template

ICT
Information and communications technology

IIoT
Industrial Internet of Things

IT
Information technology

KPI
Key performance indicator

KQI
Key quality indicator

MDAS
Management data analytics service

mMTC
Massive machine-type communication

MNO
Mobile network operator

MTBF
Mean time between failure

MTTR
Mean time to repair

NPN
Nonpublic network

NWDAF
Network data analytics function

OT
Operational technology

PLMN
Public land mobile network

QoS
Quality of service

RACI
Responsible, accountable, consulted, and informed

SLA
Service-level agreement

SLS
Service-level specifications

SNPN
Standalone NPN

UE
User equipment

URLLC
Ultrareliable low-latency communication

V2X
Vehicle to everything

9 References

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10 Appendix – Clarification of SLS Attributes

The attributes discussed above have been defined in the variant standardization forum, but it may still not be fully clear to some ICT or OT partners how to interpret their meaning and the relationships among multiple relevant attributes. This section attempts to clarify them.

10.1 Clarification of Communication Service Reliability and Availability

The key performance requirements for cyber-physical control applications in vertical domains have been captured in 3GPP TS 22.104 Release 17. One of the fundamental facets of industrial-grade SLS is the 5G system's reliability and availability. From a communication system design perspective, these attributes define how dependably a 5G service could be used to support industrial use cases and, if connectivity is lost, how quickly it could be restored (and with what kinds of effort). The same level of communication service availability (e.g. 99.9999 %) may be required for different production services in the same factory (e.g. motion control, mobile control panels, and process automation). However, the communication service reliability that these production services require may vary significantly, with mean times between failure (MTBF) ranging from one month to 10 years (see the example in Table 9).

Communication service availability can be estimated on the basis of the MTBF and mean time to repair (MTTR) of the communication service [14]:

Communication service availability ≈ MTBF / (MTBF + MTTR)

Practically speaking, the impact margin (e.g. the value lost when production stops) and often also the safety level of the industrial applications may determine the tolerance for communication system failure. Other constraints are regularity stipulations, for instance the mandatory maximum reaction time of a fail-safe production system.

Table 9: Service performance requirements for periodic deterministic communication; source: [6]

Communica¬tion service availability:	Communication service reliability: mean time between failures	Remarks
99.9999 % to 99.999999 %	~ 10 years	Motion control
99.9999 % to 99.999999 %	~ 1 month	Mobile control panels – remote control of e.g. assembly robots, milling machines
99.9999 % to 99.999999 %	≥ 1 year	Process automation – closed loop control

Please note that the service performance requirements defined by TS 22.104 *refer to individual logical communication links*, not an overall production system. All production-critical applications typically operate concurrently. So if any one of them fails this affects at least part of the overall production process. Therefore, factory owners prefer SLSs that cover the totality of services consumed. However, it makes a great deal of sense to specify in the SLSs those applications that have critical demands (and run concurrently).

10.2 Clarification of Failure and Survival Times

Many factors affect the productivity of a manufacturing process. This section reviews common causes for productivity losses and discusses how these causes are linked to the services provided by the wireless communication system supporting the production process. Part of the total productive maintenance methodology developed by Seiichi Nakajima [15], dubbed the Six Big Losses,[16] is a practical tool that can help identify inefficiencies in production.

One of the well-discussed performance characteristics of a wireless communication system relevant to productivity losses is the ability to successfully deliver an expected message prior to an application's deadline, which is commonly referred to as the survival time [6]. This is an essential parameter of SLSs. When the survival time is exceeded, typically the application using the communication service triggers an alarm, and in some cases an emergency shutdown of the application takes place. This unplanned stop can lead to production downtime and directly add to productivity losses. Use cases of this kind can include seamlessly integrated wired and wireless components for motion control, local/remote control-to-control communication, mobile robots and AGVs, and closed-loop control for process automation (see [17] for more details).

The implications of survival time typically differ from one use case to another. However, for use cases with critical requirements (e.g. in terms of reliability and latency), its definition may have major implications. For instance, if the survival time is fairly long (100 ms or more), when an application detects that the communication service is in the "survival time" zone it may prepare for an emergency shutdown for safety reasons. A similar parameter is the grace time (see IEC 62439 [19] for details). It's therefore essential for the OT to specify how often the communication service may have "survival time" status. This information can be utilized by the 5G system for SLS assurance purposes.

11 5G-ACIA Members

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5G-ACIA White Paper
Service-Level Specifications (SLSs) for 5G Technology-Enabled Connected Industries

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